Overview

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Introduction

This overview of the National Science Board's *Science and Engineering Indicators 2006* describes some major U.S. and international science and technology (S&T) developments. It focuses on trends since about 1990, although it occasionally takes a longer view. The overview synthesizes selected major findings in a meaningful way and is not intended to be comprehensive. The reader will find many important findings in the report that are not covered in the overview, e.g., public support for science is strong even though public knowledge is limited; S&T activities in different states vary substantially in size and scope; and some of those who are employed in S&T occupations lack S&T degrees, although many people with S&T degrees work in other types of jobs. The interested reader will find more extensive data in the body of the report; major findings on particular topics appear in the Highlights sections that precede chapters 1–7.

The reader should note the indicators included in *S&E Indicators 2006*, which derive from a variety of national, international, and private sources, may not be comparable in a strict statistical sense, especially for international data. In addition, some metrics and data are somewhat weak, and models relating them to each other and to economic and social outcomes are not well developed. Thus, even though many data series conform generally to international standards, the focus is on broad trends that should be interpreted cautiously.

The overview begins with a broad picture of major developments that are changing the location and conduct of international research and development and are recasting international high-technology markets. It then discusses changes in scientific research that, although less pronounced, show paths similar to earlier technology trends. Next it reviews evidence of widespread international upgrading of education levels and the increasing international mobility of highly educated individuals, especially since the 1990s. The analysis then examines relevant S&T patterns and trends in the United States on which these external changes have a bearing. To the extent possible, the overview presents comparative data for the United States, the European Union (EU) before enlargement,[1] Japan, China, and eight other selected Asian economies (Asia-8).[2]

S&T: The Global Picture

For S&T, it is a changed world.

Since the early 1990s, the globalization of S&T has proceeded apace. The demise of the Cold War political order precipitated more open borders just as the Internet became a tool for unfettered worldwide information dissemination and communication. Dense and relatively inexpensive airline links developed in response to a growing demand for both business and leisure travel. A more integrated trade regimen stimulated a vast expansion of international trade in goods and services. Governments increasingly looked to the development of knowledge-intensive economies—those in which research, its commercial exploitation, and other intellectual work have a major role—for economic competitiveness and growth. Companies seeking new markets set up operations in new locations, bringing with them technological know-how and management expertise. Governments anticipated and stimulated such moves with incentives, decreased regulatory barriers, development of infrastructure, and expanded access to higher education.

Asian countries outside Japan are increasingly important in the global S&T community.

The major development since the mid-1990s was the rapid emergence of Asian economies outside of Japan as increasingly strong players in the world's S&T system. South Korea and Taiwan were already well established in particular markets, and Singapore, Malaysia, Thailand, and others boosted their market strength and showed potential for further increases in competitiveness. China is growing at the most rapid pace, and its government has declared education and S&T to be the strategic engines of sustainable economic development. China has already become an important player in high-technology markets, has attracted the world's major corporations, and in 2004 was the world's largest recipient of foreign direct investment. In the area of scientific research, China does not yet approach parity with major science-producing nations, but its scientists and engineers are collaborating broadly with their counterparts in Asia and across the globe. In addition, China's international patenting and publishing activities, although still modest, are fast increasing. Fragmentary data on India suggest that it is also seeking rapid technological development focusing on knowledge-intensive service sectors and biotechnology.

Ubiquitous growth is coupled with share losses for traditional S&T locations.

The developments stated above are recasting the international S&T scene. In an absolute sense, growth is ubiquitous in both funding and personnel devoted to S&T activities and in outputs from these activities, including scientific articles, patents, and high-technology products. In a relative sense, the major European nations and the EU countries as a group are losing ground, as is Japan, whereas the United States is maintaining its position across a variety of measures. China is making large relative gains as are, to a lesser degree, other Asian economies. Other areas of the world such as Eastern Europe, central Asia, the Middle East, Latin America, and Africa, are slowly and selectively entering the international S&T scene but do not yet play a major role in the world's S&T system.

International R&D Performance

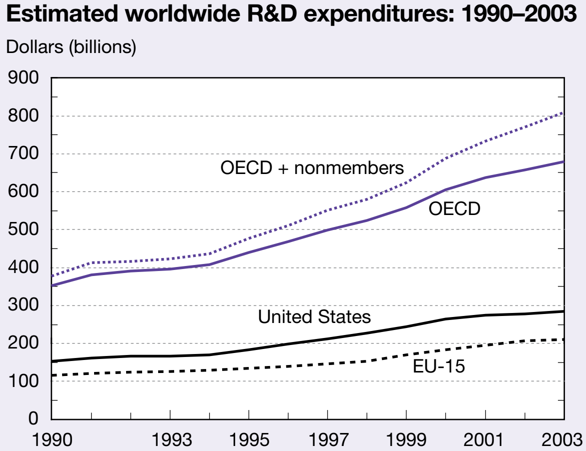
International R&D spending has seen robust increases.

Rising R&D expenditures are no longer limited to the member countries of the Organisation for Economic Co-operation and Development (OECD).[3] Based on OECD and nonmember economies,[4] the (underestimated) worldwide R&D expenditures, unadjusted for inflation, rose from $377 billion in 1990 to $810 billion in 2003, the last year of available data. The OECD countries' share dropped from an estimated 93% to 84% of the total over the period, based on the reported R&D expenditures of eight non-OECD members whose 1995–2003 average annual growth rate of 17.1% compared with 5.6% annual growth for OECD members (figure O-1).

Industrial R&D investments outpace those of governments.

Governments around the world are increasing their R&D funding in support of the development of high-technology industries. However, industry R&D support has often expanded more rapidly, leading to a declining share of government support in total R&D in many countries. The relative decline in the United States had been very steep—the federal government share fell from 48% in 1990 to a low of 26% in 2001. Changes after September 11, 2001, largely in defense and national security R&D, brought it back up to 31% in 2004. In the EU, the government share diminished from 41% in 1990 to 34% in 2001 (more current data are unavailable). Germany's 32% rate in 2003 was close to its 1990 level of 34%, after rising as high as 38%. Japan's rate, by far the lowest among OECD countries, has fluctuated between 18% and 23% over the period (figure O-2).

Figure O-1
Estimated worldwide R&D expenditures: 1990–2003



EU = European Union; OECD = Organisation for Economic Co-operation and Development

NOTE: Current dollars converted with purchasing power parities.

SOURCE: OECD, *Main Science and Technology Indicators* (various years).

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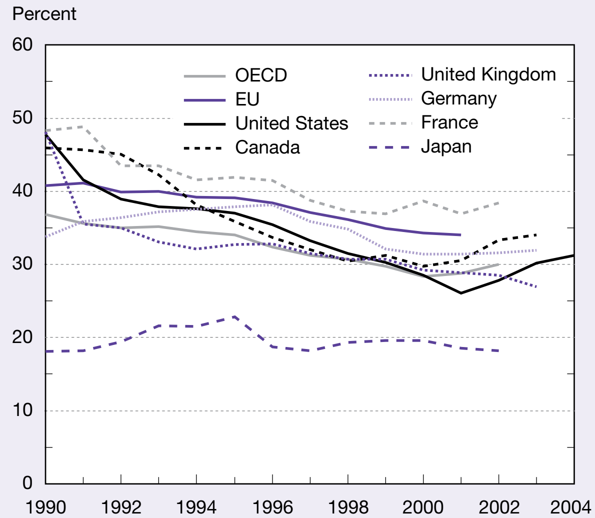
Figure O-2
Government funds as share of gross expenditures for R&D: 1990–2004



EU = European Union; OECD = Organisation for Economic Co-operation and Development

NOTE: Current dollars converted with purchasing power parities.

SOURCE: OECD, *Main Science and Technology Indicators* (various years).

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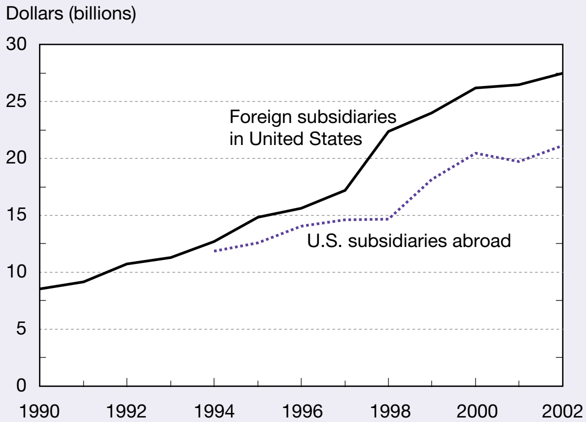
Firms' cross-border R&D investments are increasing, as are cross-border alliances.

Industry is increasingly looking beyond national borders in the location of R&D activities, and the United States remains an attractive venue for foreign companies seeking to conduct R&D. From 1990 to 2002, R&D expenditures in the United States by majority-owned affiliates of foreign-based multinationals rose from 8% to 14% of total U.S. industrial R&D performance. R&D expenditures by U.S.-owned companies abroad rose from about $12 billion in 1994 to $21 billion in 2002 (figure O-3). In the United Kingdom, more than a quarter of its industrial R&D was supported by foreign sources in 2002, while Canada's foreign support rose to 21% and the EU-15's rose to 10%, including within-EU funds flows.

The global nature of S&T markets is also reflected in the rising number of companies' international alliances devoted to joint R&D or technology development. Industrial innovation increasingly involves external partners to complement internal capabilities, share costs, spread market risk, expedite projects, and increase sensitivities to geographic variations in product markets. To accomplish these ends, companies have resorted to a variety of technology alliances, often crossing national boundaries. The number of new international alliances rose from under 100 in 1980 to 183 in 1990 and 342 early in the new century. Historically, U.S. companies have been involved in 75% to 86% of these alliances (figure O-4).

Overseas, R&D spending by U.S.-based multinationals is increasing in Asia. Although Europe remains the single largest location of these R&D expenditures, accounting for just over 60% of the total, its share has slipped by about 10 percentage points since 1994. Over the period, the combined share of Europe, Canada, and Japan declined from 90% to 80% of the total. The share of other Asian economies rose from 5% to 12% as R&D expenditures by U.S.-based multinationals more than doubled in the region starting in 1999, to about $3.5 billion, compared with $1.5 billion during the 1994–98 period. This increase was fueled primarily by steep investment growth in China (more than $1 billion in 2002 and rising) and the Asia-8 economies. U.S. R&D expenditures in Japan increased only moderately (figure O-5).

Figure O-3
R&D expenditures of foreign-owned firms in United States and of U.S.-owned firms abroad: 1990–2002



SOURCES: U.S. Department of Commerce, Bureau of Economic Analysis, Survey of Foreign Direct Investment in the United States (annual series), http://www.bea.gov/bea/di/di1fdiop.htm; and Survey of U.S. Direct Investment Abroad (annual series), http://www.bea.gov/bea/di/di1usdop.htm. See appendix tables 4-49 and 4-51.

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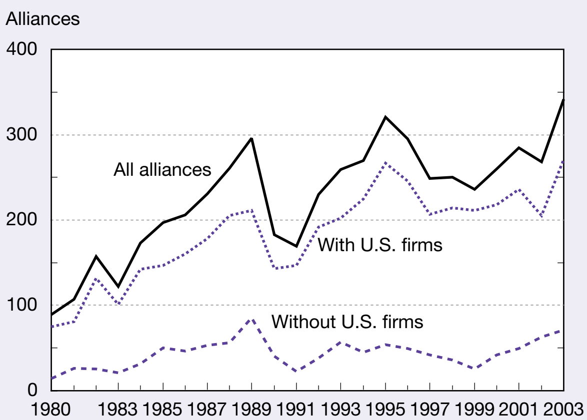
Figure O-4
New international technology alliances by membership: 1980–2003



NOTE: Includes business alliances with joint R&D or technology development agreements, contracts, or equity joint ventures.

SOURCE: Maastricht Economic Research Institute on Innovation and Technology, Cooperative Agreements and Technology Indicators (CATI-MERIT) database, special tabulations. See appendix table 4-37.

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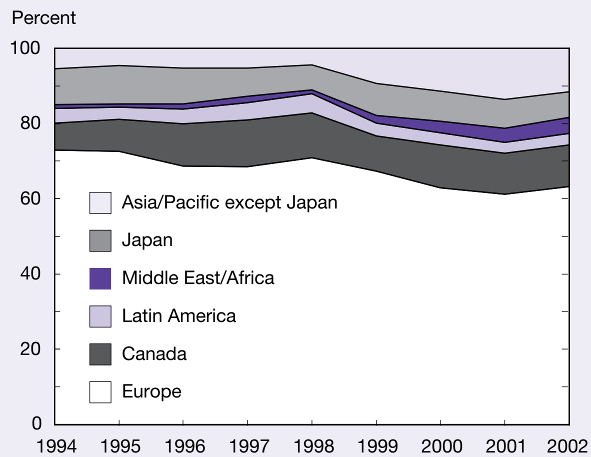
China has become the world's third-largest R&D performer.

According to data compiled by OECD, Chinese R&D spending reached $84.6 billion in 2003, up from $12.4 billion in 1991. Although a question remains about the precise international comparability of the data, this would put China in third place, behind only the United States and Japan and ahead of Germany. Average annual increases in R&D investment over the 12-year period ranged from 4% to 5% for the United States, EU-25,[5] and Japan. These contrasted sharply with the 17% average annual growth for China, which is accelerating: for the past 5 years, China's R&D expenditures have registered 24% average annual increases. Over the period, China's R&D/gross domestic product ratio, indicative of the relative prominence of R&D in China's rapidly growing economy, rose from 0.6% to 1.3%, compared with about 1.8% for the EU-15 and 2.6% for the United States (figure O-6).

China's R&D expenditures are rapidly approaching those of Japan, the second largest R&D-performing nation. OECD data show China's investment at 17% of Japan's in 1991 but at 74% of Japan's in 2003. Relative to the EU-25, the comparable Chinese figures were 10% and 40%, and relative to the United States the increase was from 8% to 30% (figure O-7). Even if more fully comparable Chinese figures reduced the growth statistics somewhat, such a rapid advance on the leading R&D-performing countries and regions would still be unprecedented in recent history. It is underscored by the growth of China's industrial research workforce, which expanded from 16% of

Figure O-5
Geographic distribution of U.S. firms' overseas R&D: 1994–2002



NOTE: R&D performed overseas by majority-owned affiliates of U.S. firms.

SOURCE: U.S. Department of Commerce, Bureau of Economic Analysis, Survey of U.S. Direct Investment Abroad (annual series), http://www.bea.gov/bea/di/di1usdop.htm. See appendix table 4-51.

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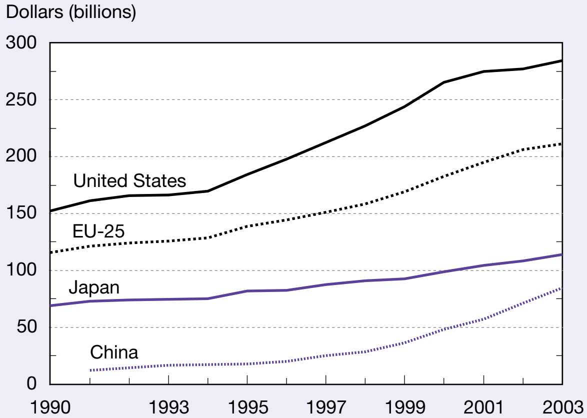
Figure O-6
R&D expenditures of selected region and countries: 1990–2003



EU = European Union

NOTES: All data calculated by Organisation for Economic Co-operation and Development (OECD) with purchasing power parities. Data differ somewhat from U.S. dollar figures. EU-25 is EU-15 plus 10 new member states.

SOURCE: OECD, *Main Science and Technology Indicators* (various years).

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the size of its U.S. counterpart in 1991 to 42% in little more than a decade.

Growth in industrial R&D creates rising numbers of researchers around the world.

The number of industrial researchers has grown along with rapidly increasing industrial R&D expenditures. Across OECD member nations, employment of researchers by industry has grown at about twice the rate of total industrial employment. For the OECD as a whole, the full-time equivalent number of researchers more than doubled, from just below 1 million in 1981 to almost 2.3 million in 2002. Over the same period, the number of researchers in the United States rose from 0.5 million to nearly 1.1 million. Non-OECD members also show increasing researcher employment (figure O-8).

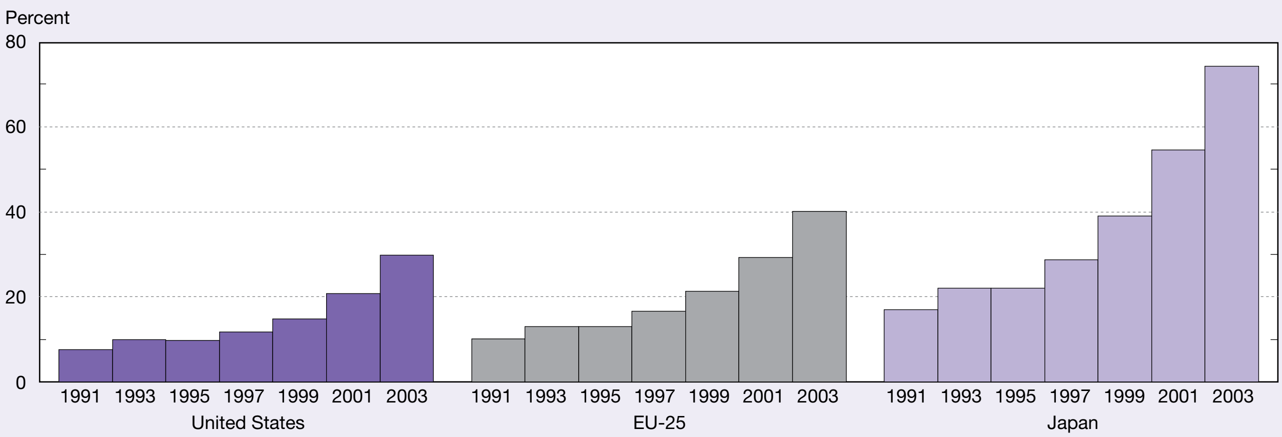
High-Technology Markets

Europe and Japan are losing market share in high-technology manufacturing

High-technology manufacturing industries embody the fruits of innovation. High-technology industry output has grown rapidly since 1990 and now comprises about one-fifth of the world's total manufacturing output. The United States, China, and other Asian economies have shifted into high-technology manufacturing sectors more rapidly than the EU-15 or Japan.

Overall world manufacturing output grew from $13.9 trillion in 1990 to $19.6 trillion in 2003 after adjusting for inflation. However, the manufacturing output of five high-technology industries (aerospace, pharmaceuticals, office and computing equipment, communications equipment, and scientific instruments) grew faster, from $1.5 trillion to $3.5 trillion. The United States and developing Asian economies largely drove the worldwide growth in high-technology manufacturing. The resulting shifts in its geographical distribution were pronounced. Shares for the United States, the EU-15, and Japan were about 25% each in 1990, but by 2003 the U.S. share had risen to nearly 40%, while those of the EU-15 and Japan had declined to 18% and 11%, respectively. In 2003, China had surpassed Japan as a producer of high-technology

Figure O-7
China's R&D expenditures relative to those of United States, Japan, and EU-25: 1991–2003



EU = European Union

NOTE: All data calculated by Organisation for Economic Co-operation and Development (OECD) with purchasing power parities.

SOURCE: OECD, *Main Science and Technology Indicators* (various years).

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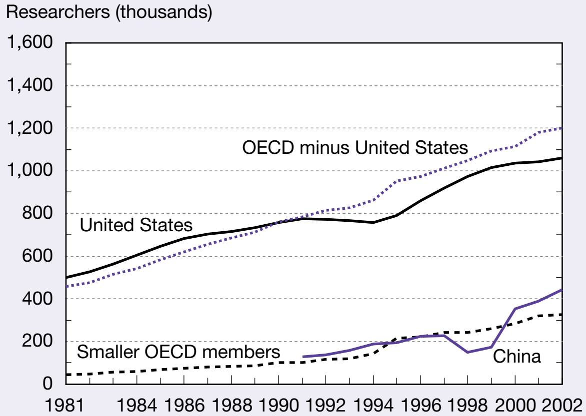
Figure O-8
Estimated number of industrial researchers, by country/region: 1981–2002



OECD = Organisation for Economic Co-operation and Development

NOTE: "Smaller OECD members" is OECD minus United States, Japan, United Kingdom, Germany, France, Italy, and Canada.

SOURCE: OECD, *Main Science and Technology Indicators* (various years).

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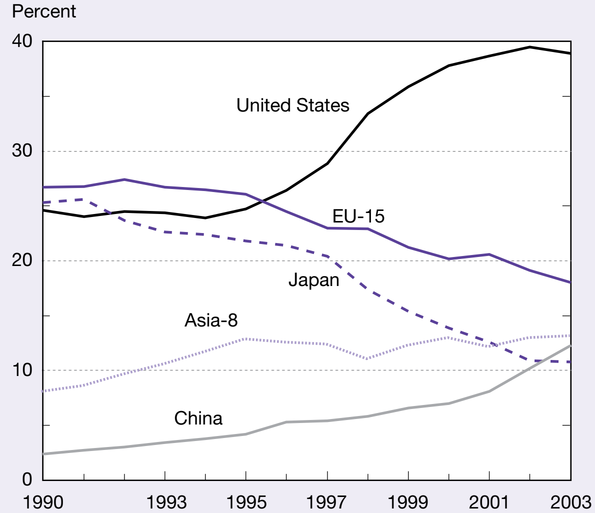
goods and accounted for 12% of the world market share, about the same as that of the Asia-8 (figure O-9).

The United States has rapidly developed the most high-technology-intensive manufacturing sector among major nations. Since 1990, U.S. high-technology manufacturing output has risen from 12% to 30% of total domestic manufacturing. The EU-15 shift was less pronounced, from 9% to 12%, and Japan's was minimal, from 14% to 15% (automobiles are excluded from the high-technology definition used here). China's fast-growing manufacturing sector (about the same size as Japan's by 2003) shifted rapidly toward high-technology production, boosting this component from 6% in 1990 to 18% in 2003. For the Asia-8, the high-techno logy manufacturing component expanded from 13% to 23% (figure O-10).

High-technology shares of Asian exporters are expanding.

Exports of all manufactured goods more than doubled from 1990 to 2003, but high-technology exports had greater increases and reached $1.9 trillion in 2003. The single largest volume was that of the EU-15, at almost one-third of the total since the mid-1990s; the combined Asia-8 exports were the second highest (figure O-11). The shares of China and the Asia-8 economies rose at the expense of the United States and Japan. U.S. high-technology exports stood at $305 billion in 2003, essentially the same level as in 2000, and the U.S. share declined from 23% to 16% during this period. The Japanese share dropped from 17% to 9%. China's rise from a mere $23 billion in 1990 to $224 billion in 2003, remarkable both for its speed and consistency, moved its share of world high-technology exports to 12%, beyond Japan's share.

Figure O-9
Location of world's high-technology manufacturing output: 1990–2003



EU = European Union

NOTE: Asia-8 includes South Korea, India, Indonesia, Malaysia, Philippines, Singapore, Taiwan, and Thailand.

SOURCES: Global Insight, Inc., World Industry Service database (2005). Historical data from United Nations Industrial Development Organization, United Nations System of National Accounts, Organisation for Economic Co-operation and Development, and country sources. See appendix table 6-2.

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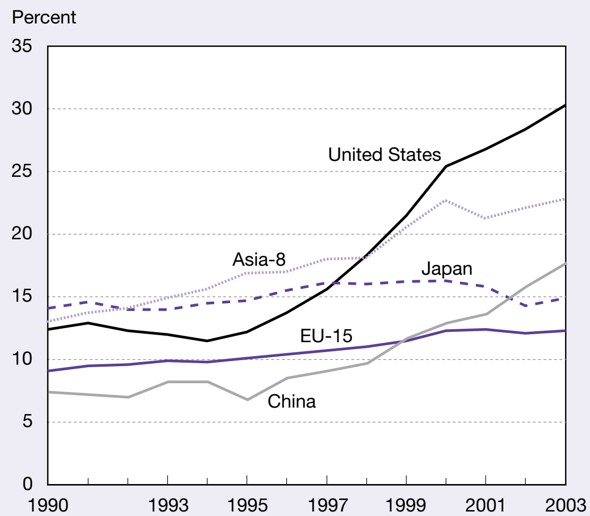
Figure O-10
High-technology share of total manufacturing, by country/region: 1990–2003



EU = European Union

NOTE: Asia-8 includes South Korea, India, Indonesia, Malaysia, Philippines, Singapore, Taiwan, and Thailand.

SOURCES: Global Insight, Inc., World Industry Service database (2005). Historical data from United Nations Industrial Development Organization, United Nations System of National Accounts, Organisation for Economic Co-operation and Development, and country sources. See appendix table 6-2.

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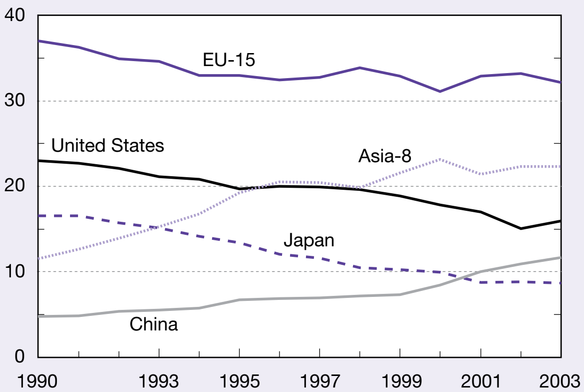
Figure O-11
Export market shares in high-technology goods, by country/region: 1990-2003



EU = European Union

NOTES: Asia-8 includes South Korea, India, Indonesia, Malaysia, Philippines, Singapore, Taiwan, and Thailand. These countries/regions account for 91%–93% of world total.

SOURCES: Global Insight, Inc., World Industry Service database (2005). Historical data from United Nations Industrial Development Organization, United Nations System of National Accounts, Organisation for Economic Co-operation and Development, and country sources. See appendix table 6-4.

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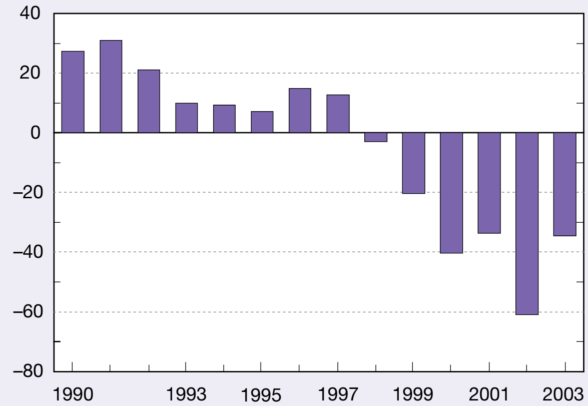
Figure O-12
U.S. trade balance for five high-technology industries: 1990–2003



NOTE: Includes aerospace, pharmaceuticals, office and computing equipment, communications equipment, and scientific instruments.

SOURCES: Global Insight, Inc., World Industry Service database (2005). Historical data from United Nations Industrial Development Organization, United Nations System of National Accounts, Organisation for Economic Co-operation and Development; and country sources. See appendix table 6-4.

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The U.S. high-technology trade balance is negative.

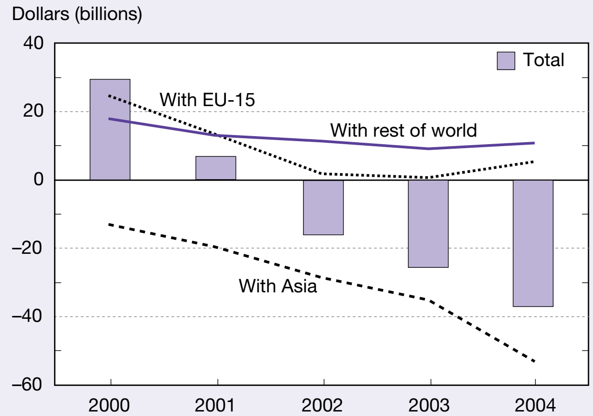
The U.S. high-technology trade balance, which broadly reflects relative economic strengths and foreign exchange rate movements, has been closely watched as an indication of the international competitiveness of the nation's high-technology industries. For the first time in recent memory, the U.S. high-technology trade balance turned negative in the past several years (figure O-12). Trade data for five high-technology manufacturing industries (aerospace, pharmaceuticals, office and computing equipment, communications equipment, and scientific instruments) show that, beginning in 1998, U.S. high-technology industries' imports exceed exports.

U.S. trade in goods with high-technology content yields a similar picture. For 10 high-technology product categories (biotechnology, life sciences, optoelectronics, information and communications equipment, electronics, flexible manufacturing, advanced materials, aerospace, weapons, and nuclear technology), U.S. trade turned negative in 2002 and stayed that way through 2004, the latest year for which data are available (figure O-13). A negative balance with the Asian region is partially offset by positive balances with the EU-15 and the rest of the world.

Increasing Asian patent filings show growing technological sophistication.

Strong growth in the number of applications for U.S. patents by foreign-resident inventors, particularly from Asia, attests to the increase in technological sophistication in other parts of the world. The number of such filings has historically been just under half of the growing number of U.S. Patent and Trademark Office filings. Applications from Japanese inventors, traditionally the largest group of foreign filers, rose by about 75%, as did those from filers in Europe and other areas. However, as with many economic statistics, other Asian economies are an exception. Applications from China and the Asia-8 rose by 800% and, by 2003, constituted nearly one-fifth of all foreign-resident inventor filings (figure O-14). South Korea and Taiwan have now joined Japan among the top five inventor locations.

Figure O-13
U.S. trade balance in high-technology goods: 2000–04



EU = European Union

SOURCE: U.S. Census Bureau, Foreign Trade Division, special tabulations (March 2005). See appendix table 6-6.

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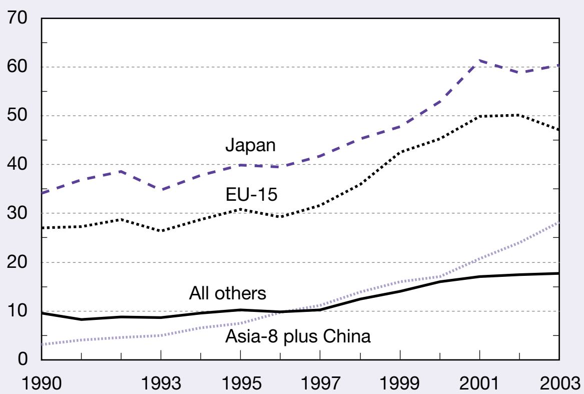
Figure O-14
U.S. patent applications by foreign-resident inventors: 1990–2003



EU = European Union

NOTE: Asia-8 includes South Korea, India, Indonesia, Malaysia, Philippines, Singapore, Taiwan, and Thailand.

SOURCE: U.S. Patent and Trademark Office, Office of Electronic Information Products, Patent Technology Monitoring Division, special tabulations (December 2004). See appendix table 6-13.

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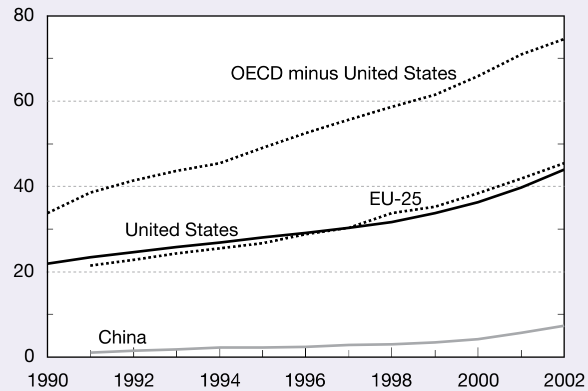
Figure O-15
Academic R&D expenditures: 1990–2003



EU = European Union; OECD = Organisation for Economic Co-operation and Development

NOTES: All data calculated by OECD with purchasing power parities. EU-25 is EU-15 plus 10 new member states.

SOURCE: OECD, *Main Science and Technology Indicators* (various years).

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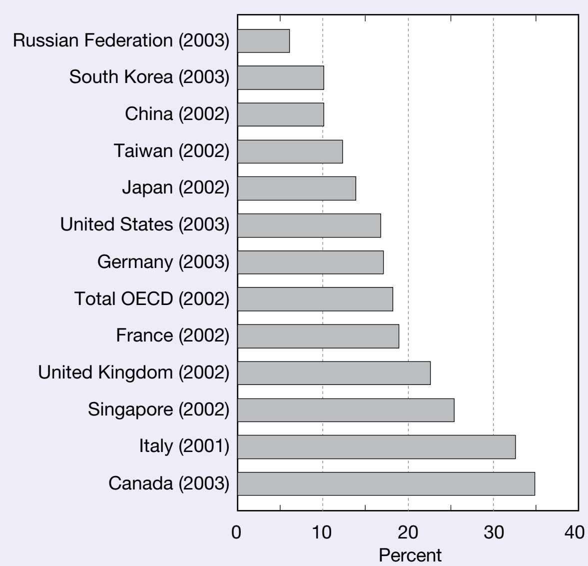
Scientific Research

Academic R&D has grown robustly but remains less prominent in Asia.

Academic R&D has seen robust growth in many countries as governments try to stimulate basic research capability and to connect universities with industry for the efficient exploitation of research results. The United States and the EU-25 (including 10 new member countries) have been spending similar amounts for academic R&D, $41 to $44 billion in 2003, about double their expenditures in 1990. OECD nations other than the United States spent $74 billion, an increase of 120% over 1990. However, China has experienced the most rapid growth in its spending for academic R&D, from $1.1 billion in 1991 to $7.3 billion in 2002, with double-digit growth rates since 1999 (figure O-15).

Nevertheless, the academic sector, where basic research is conducted in many countries, plays a relatively small role (about 10%) in China's R&D system. This is also the case in some other Asian countries, where R&D tends to focus more on applied research and especially on development. In other major OECD nations, the share of academic R&D was at least 14% (figure O-16).

Figure O-16
Academic R&D as share of total R&D, by country/economy: Most recent year



OECD = Organisation for Economic Co-operation and Development

SOURCE: OECD, *Main Science and Technology Indicators* (various years).

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Scientific expertise is expanding, which diminishes the U.S. quality advantage.

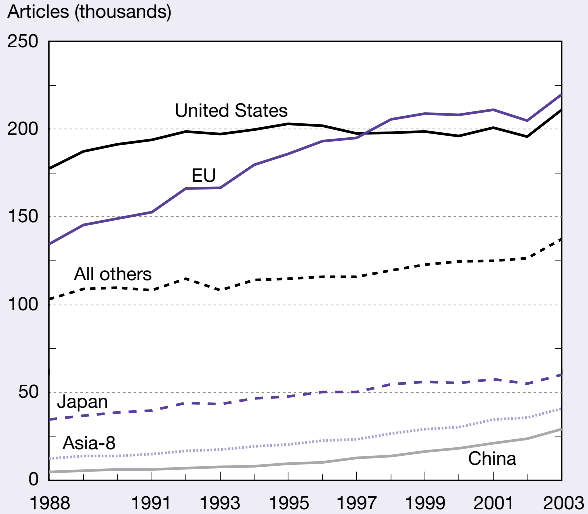
Scientific expertise is developing rapidly outside the established scientific centers of the United States, the EU, and Japan, as shown by research articles published in the world's major peer-reviewed scientific and technical journals. The total number of articles rose from 466,000 in 1988 to 699,000 in 2003. Over the period, the combined share of the United States, Japan, and the EU-15 declined from 75% to 70% of the total, with flat U.S. article output from 1992 to 2002, leading to a drop of the U.S. share from 38% to 30%. Meanwhile, EU-15 output rose steadily to surpass that of the United States in 1998, and Japan's output also continued to rise. Output from China and the Asia-8 expanded rapidly over the period, by 530% and 235%, respectively, boosting their combined share of the world total from less than 4% in 1988 to 10% in 2003. By 2003, South Korea ranked 6th and China ranked 12th in world article output. Increases in other parts of the world tended to be more modest (figure O-17).

Scientists acknowledge their colleagues' relevant work by citing it, and the aggregate of these citations provides an approximate measure of quality. Relative to its publications volume, U.S. scientific literature continues to receive a disproportionate share of all international citations. However, a closer look reveals that the quality of scientific output produced outside the United States is rising. An examination of articles published in the most prestigious journals included in the Science Citation Index[6] reveals that, in almost every field, the U.S. share of citations, while high, has declined significantly since 1990. The U.S. share of citations in the highest-cited articles has declined as well (figure O-18). In both cases, the declines are broadly proportional to the progressively lower share of U.S. articles.

International collaboration is commonplace.

The manner in which science and engineering is conducted is becoming increasingly international in response to the growing complexity of science, ease of face-to-face contact, the Internet, and government incentives. Overall, about 20% of the world's scientific and technical articles in 2003 had authors from two or more countries, compared with 8% in 1988. One-quarter of articles with U.S. authors have one or more international coauthors, which is similar to the percentages for Japan, China, and the Asia-8 (figure O-19). The higher EU level partially reflects the EU's emphasis on collaboration among the member countries as well as the relatively small science establishments of some members. Other countries'

Figure O-17
Scientific and technical articles, by country/region: 1988–2003



EU = European Union

NOTE: Asia-8 includes South Korea, India, Indonesia, Malaysia, Philippines, Singapore, Taiwan, and Thailand.

SOURCES: Thomson ISI, *Science Citation Index* and *Social Sciences Citation Index,* http://www.isinet.com/products/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-41.

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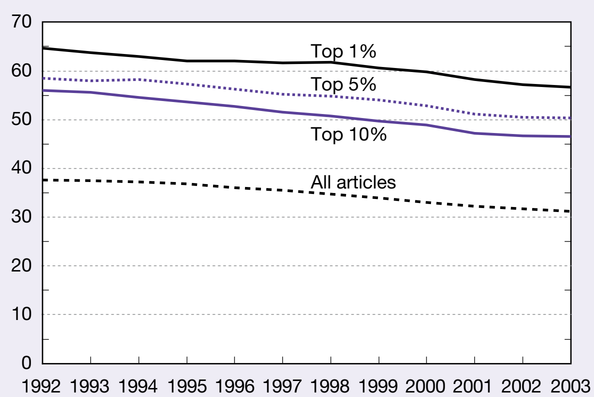
Figure O-18
Share of U.S. articles among most-cited articles, total S&E: 1992–2003



NOTE: Three years of article citations, lagged by 2 years.

SOURCES: Thomson ISI, *Science Citation Index* and *Social Sciences Citation Index,* http://www.isinet.com/products/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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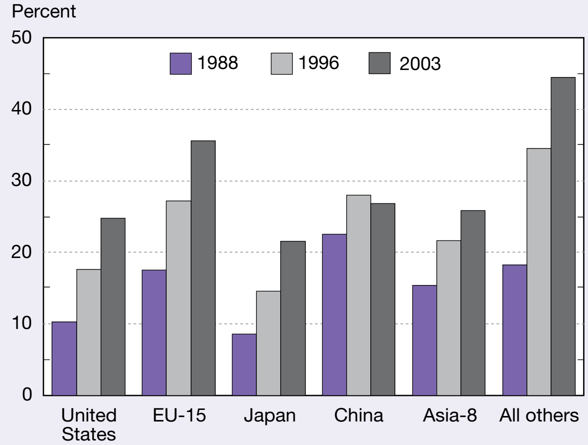
Figure O-19
Share of scientific and technical articles with international coauthorship, by country/region: 1988, 1996, and 2003



EU = European Union

NOTE: Asia-8 includes South Korea, India, Indonesia, Malaysia, Philippines, Singapore, Taiwan, and Thailand.

SOURCES: Thomson ISI, *Science Citation Index* and *Social Sciences Citation Index,* http://www.isinet.com/products/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix tables 5-47, 5-48, and 5-49.

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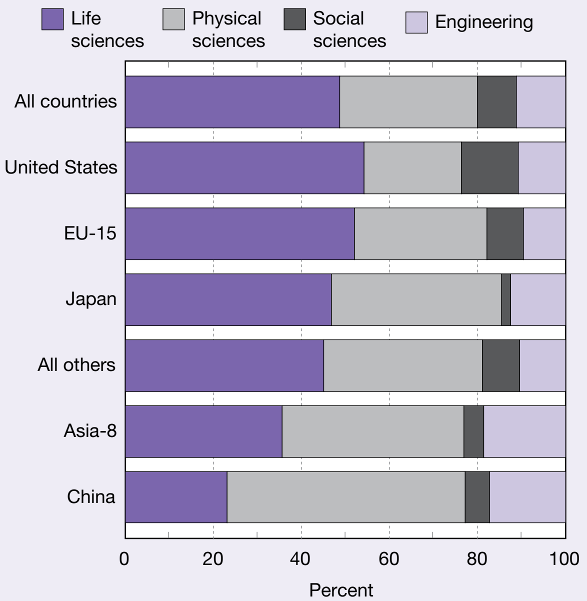
Figure O-20
Portfolio of scientific and technical articles, by field and country/region: 2003



EU = European Union

NOTES: Asia-8 includes South Korea, India, Indonesia, Malaysia, Philippines, Singapore, Taiwan, and Thailand. Countries/regions ordered by percentage of life sciences.

SOURCES: Thomson ISI, *Science Citation Index* and *Social Sciences Citation Index,* http://www.isinet.com/products/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 5-45.

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high levels of collaboration reflect science establishments that may be small (e.g., in developing nations) or that may be in the process of rebuilding (e.g., in Eastern European countries). Generally, international collaboration is lower in the social sciences than in other fields.

By choice or by legacy, international science portfolios vary greatly.

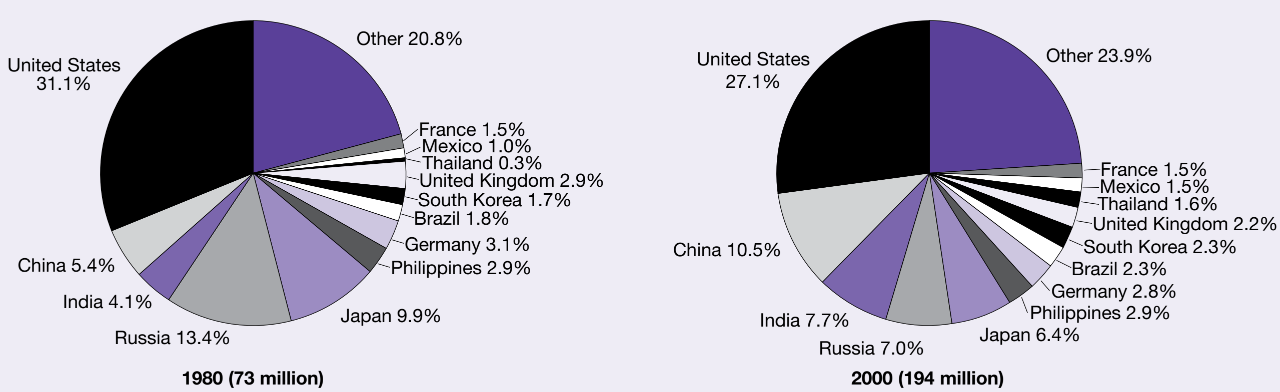
The scientific portfolios of the emerging Asian countries suggest a relatively greater specialization in the physical sciences and engineering than that of the traditional scientific centers. In 2003, more than half of China's publications concentrated on the physical sciences and nearly another fifth concentrated on engineering; in comparison with the rest of the world, the life sciences and social sciences constituted a very small share. The sum of eight other Asian portfolios showed a similar pattern. In contrast, the literature from both the United States and the EU-15 showed a fairly heavy emphasis on the life sciences (45%–54%) and a relatively lighter share in engineering (10%–13%) and the physical sciences (22%–39%) (figure O-20). The literature from Japan falls in between these two ranges. These portfolio patterns have changed little since the mid-1990s.

International Labor Forces, Students, and Degrees

International S&E labor force data can only be estimated.

International S&E labor force data are unavailable; however, the number of people with a postsecondary education can serve as an approximate measure of a highly educated S&E workforce. It shows enormous growth over two decades, from about 73 million in 1980 to 194 million in 2000. This broad measure of those who are highly skilled includes persons with at least a technical school or associate's degree and all advanced degrees (including doctorates and professional degrees). Over the period, the U.S. share of the total, which was the largest share, fell from 31% to 27%. China's and India's shares doubled to 10% and 8%, respectively, while Russia's share decreased by nearly half but remained the fourth largest. None of these three large countries are OECD members. A number of developing nations increased their share, indicating a broader provision of higher education (figure O-21).

Figure O-21
Population 15 years old or older with tertiary education by country/region: 1980 and 2000



SOURCE: Adapted from R.J. Barro and J.W. Lee, Center for International Development, *International Data on Educational Attainment* (2000).

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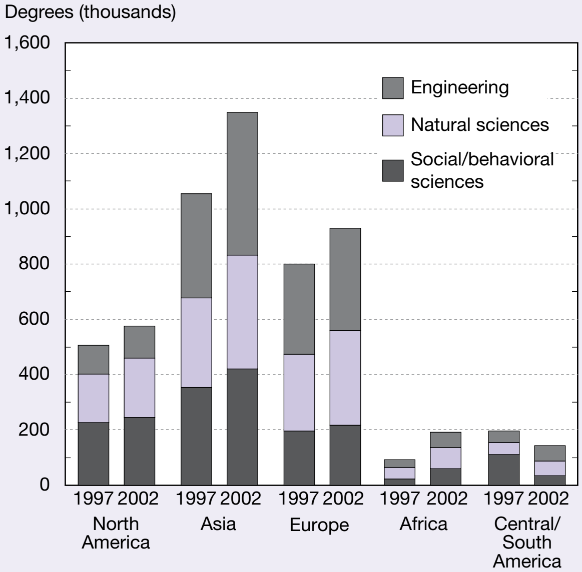
International degree production is rising and is focused on S&E.

The number of first university degrees awarded around the world is rising rapidly, from about 6.4 million in 1997 to 8.7 million in 2002. Particularly strong increases occurred in Asia and Europe, with large numbers and strong gains in engineering and the natural sciences. In 2002, engineering degrees awarded in Asia were more than four times the amount of those awarded in North America, and the number of natural science degrees was nearly double. Europe graduated three times as many engineers as North America in 2002 (figure O-22).

The share of S&E degrees among first university degrees in the United States is lower than in other countries, as is the share of U.S. degrees in natural sciences and engineering (NS&E) (i.e., S&E degrees without the social sciences and psychology). Just under one-third of all U.S. degrees are awarded in S&E. This statistic has held steady over the years, along with the 19% share of NS&E degrees. However, world trends seem to be converging. In 1997, an average of 44% of all degrees awarded in other countries were in S&E, but that number fell to 38% in 2002. Similarly, the share of NS&E degrees declined from 30% to 27%, indicating that the worldwide expansion of higher education degrees was stronger in the non-S&E fields than in S&E (figure O-23). In light of these statistics, OECD ministers have expressed concern that young people lack interest in S&E.

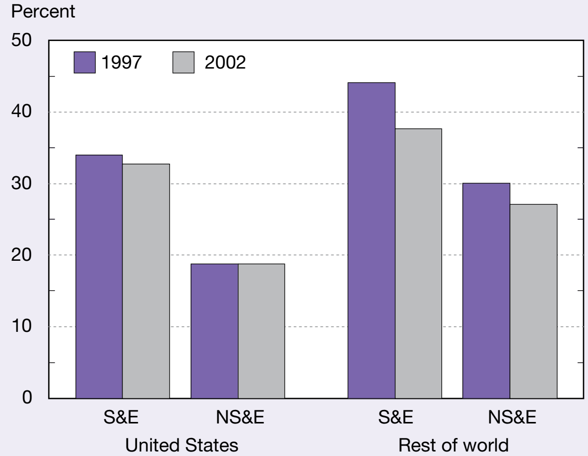
Figure O-22
First university degrees, by region: 1997 and 2002



SOURCES: Organisation for Economic Co-operation and Development, Center for Education Research and Innovation, Education database, http://www1.oecd.org/scripts/cde/members/EDU_UOEAuthenticate.asp; United Nations Educational, Scientific, and Cultural Organization (UNESCO), Institute for Statistics, special tabulations; Iberoamerican Network of Science and Technology Indicators (RICYT), Principales Indicadores de Ciencia y Tecnología (1999); and country sources. See appendix table 2-37.

Science and Engineering Indicators 2006

Figure O-23
First university degrees in NS&E as share of total first university degrees: 1997 and 2002



NS&E = natural sciences and engineering

SOURCES: China—National Research Center for Science and Technology for Development, unpublished tabulations; Japan—Government of Japan, Ministry of Education, Culture and Science, Monbusho Survey of Education (annual series, 2005); South Korea—Organisation for Economic Co-operation and Development, Center for Education Research and Innovation, Education database, http://www1.oecd.org/scripts/cde/members/EDU_UOEAuthenticate.asp; Taiwan—Ministry of Education, Educational Statistics of the Republic of China (annual series, 2004); Germany—Federal Statistical Office, Prüfungen an Hochschulen 2003 (annual series, 2004); United Kingdom—Higher Education Statistics Agency, special tabulations (2005); and United States—U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; and National Science Foundation, Division of Science Resources Statistics, WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-38.

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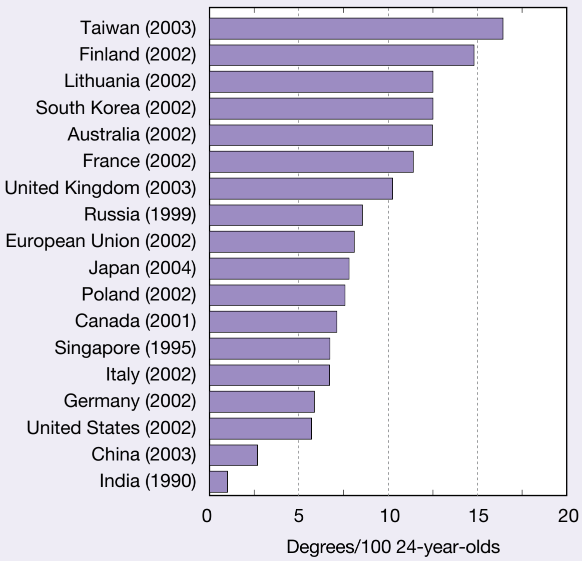
Europe and Asia have made great strides in natural science and engineering degree production.

In the context of building knowledge-intensive economies, the education of young people in NS&E has become increasingly important for many governments. Results vary widely for first university degrees in the NS&E from about 16 per 100 24-year-olds in Taiwan to 12–13 in Australia and South Korea, and 10 in the United Kingdom. The United States ranks 32nd out of 90 countries for which such data are available at just under 6 per 100. China and India have low ratios (1.6 and 1.0, respectively), reflecting low overall rates of access to higher education in those countries (figure O-24). However, this trend appears to be changing: S&E degree production in China doubled and engineering degrees tripled over the past two decades.

The international production of S&E doctorate holders has also accelerated; in recent years most of these degrees (78% in 2002) have been granted outside the United States. The EU graduated one-third of the new S&E doctorates and also one-third of those with doctorates in the natural sciences. One-third of the engineering doctorates were awarded in Asia, where numbers are understated because of incomplete

Figure O-24
NS&E degrees per 100 24-year-olds, by country/economy: Most recent year

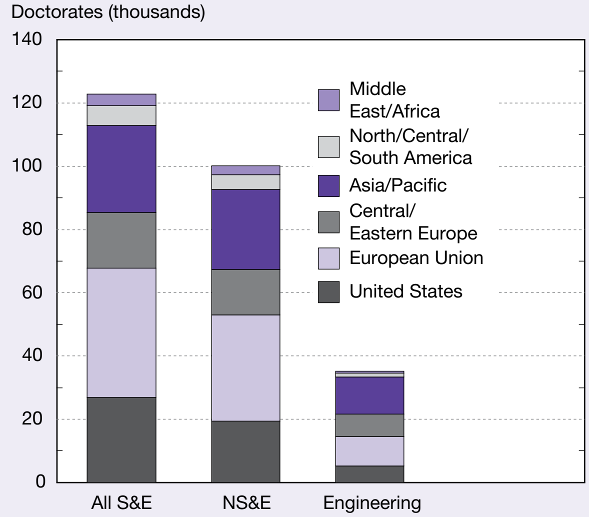


NS&E = natural sciences and engineering

SOURCES: Organisation for Economic Co-operation and Development, Center for Education Research and Innovation, Education database, www1.oecd.org/scripts/cde/members/edu_uoeauthenticate.asp; United Nations Educational, Scientific, and Cultural Organization (UNESCO), Institute for Statistics database, http://www.unesco.org/statistics, and national sources. See appendix table 2-37.

Science and Engineering Indicators 2006

Figure O-25
S&E doctorates awarded, by country/region: Most recent year



NS&E = natural sciences and engineering

SOURCES: Organisation for Economic Co-operation and Development, Center for Education Research and Innovation, Education database, www1.oecd.org/scripts/cde/members/edu_uoeauthenticate.asp; United Nations Educational, Scientific, and Cultural Organization (UNESCO), Institute for Statistics database, http://www.unesco.org/statistics. See appendix table 2-41.

Science and Engineering Indicators 2006

reporting. The United States produced 15% of the world's engineering doctorates in 2002 (figure O-25); students on temporary visas earned more than half of these degrees.

International Mobility

Large numbers of highly educated persons live outside their home countries.

In 2002,[7] close to 2 million students were enrolled in higher education institutions outside their home country, nearly one-third of them in the United States. A few countries continue to dominate the international student market. In 2002, the United States, United Kingdom, and Germany accounted for 54% of the total; three-quarters of all foreign students were enrolled in these three countries plus Australia, France, and Japan (figure O-26). However, this pattern shows signs of changing. The U.S. share has declined for several years, while those of the United Kingdom, Australia, and Japan have increased. Recently, a number of countries have expanded their efforts to attract foreign students.

The number of individuals with higher education degrees who lived outside their home countries grew by 9.5 million from 1990 to 2000. Individuals from Eastern Europe, Central and South America, and smaller Asian countries account for most of the increase, followed by Western Europe, China, India, and Africa. The number of expatriates from China, India, and Africa more than doubled. However, by 2000, home countries were absorbing relatively more of their highly educated citizens than in the past. In 1990, 1 in 6 resided abroad; by 2000 that number had dropped to 1 in 9, indicating that much of the world had developed an infrastructure capable of using these highly educated people productively (figure O-27). Among developed countries, the United Kingdom has the largest group of citizens with formal education beyond high school residing abroad, with Germany in second place. China, India, and the Philippines each have 1.0–1.2 million highly educated expatriates.

S&E Trends in the United States

The U.S. S&E Labor Force

S&E jobs play a growing role in the U.S. economy, but U.S. S&E degree production lagged growth in S&E occupations.

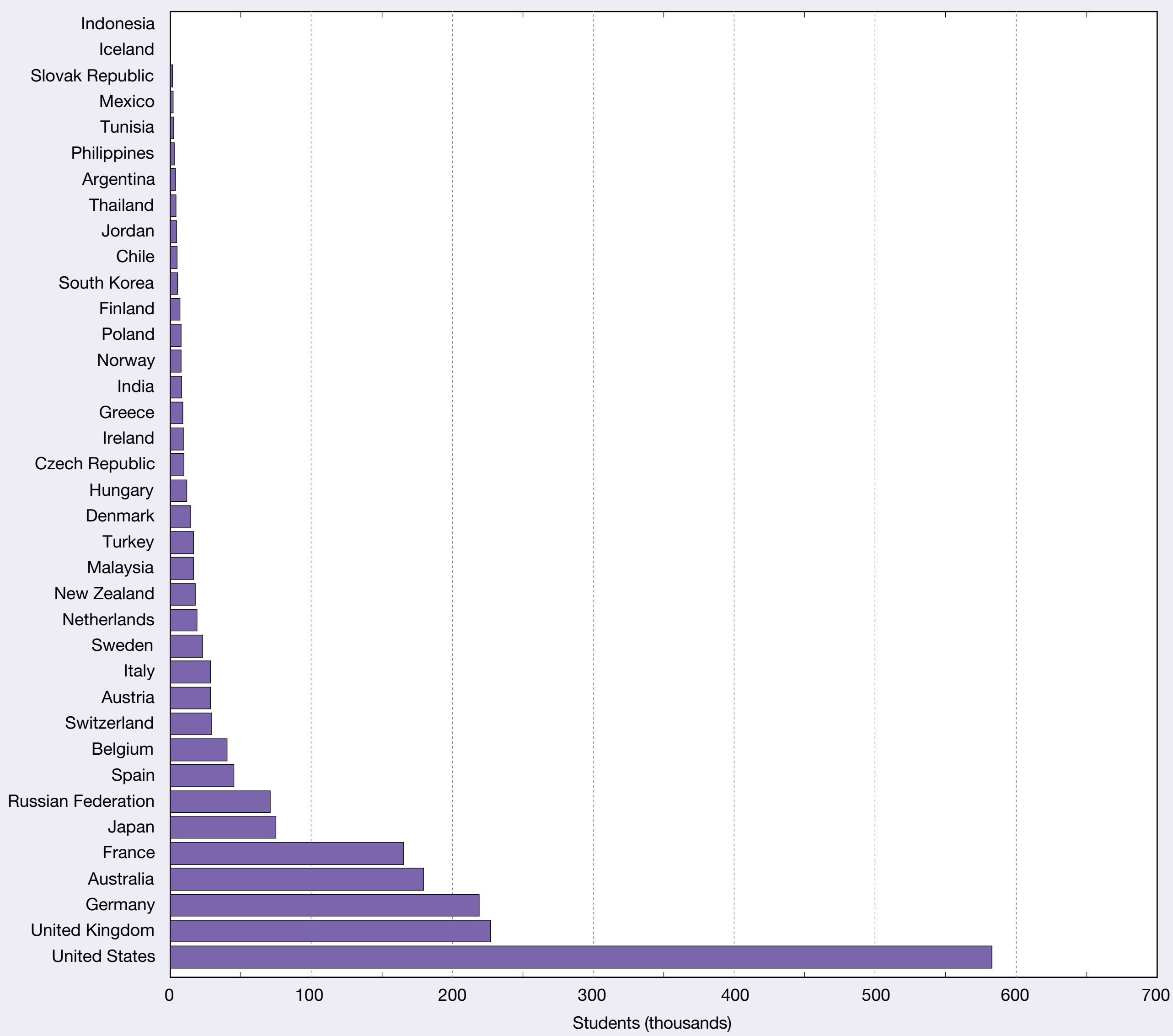
In 2003, the number of people working in S&E occupations reached 4.6 million, up from 3.3 million a decade earlier. The past decade's growth in S&E jobs continues a longer trend. In each of the past five decades, S&E jobs in the U.S. economy grew more rapidly than the overall civilian labor force. After unusually rapid increases in the 1950s (averaging about 17%), S&E employment through the 1990s rose at an annual average of 3.5%, more than three times as fast as the growth in overall civilian employment (figure O-28). In 2003, another 8.6 million holders of S&E degrees worked in jobs not classified as S&E, up from 6.5 million a decade earlier. Many of these other jobs required some S&E knowledge, indicating an increase in these jobs' technical content.

S&E degree production increased but was less than the 4% average annual growth rate of S&E employment from 1980 to 2000. The more rapid expansion of S&E jobs was made possible by the growing numbers of foreigners who earned U.S. degrees and subsequently stayed in the country, those with foreign S&E degrees who migrated to the United States for a limited period or permanently, and low retirement rates of scientists and engineers who, as a group, were younger than the overall labor force.

The influx of scientists and engineers from Asia and elsewhere accelerated in the 1990s.

The 1990s showed strong increases in the number of foreign-born individuals holding U.S. S&E jobs; by 2000, this share had increased from 14% to 22% (figure O-29). The largest increases were for doctorate holders, from 24% to 38%, and for certain job specialties. More than half of the engineers holding doctorates and 45% of doctorate holders in the physical sciences, computer sciences, and life sciences were foreign born. One-third of these foreign-born scientists and engineers came from India, China, and the Philippines; among doctorate holders, those from China and India alone comprised one-third of the total.

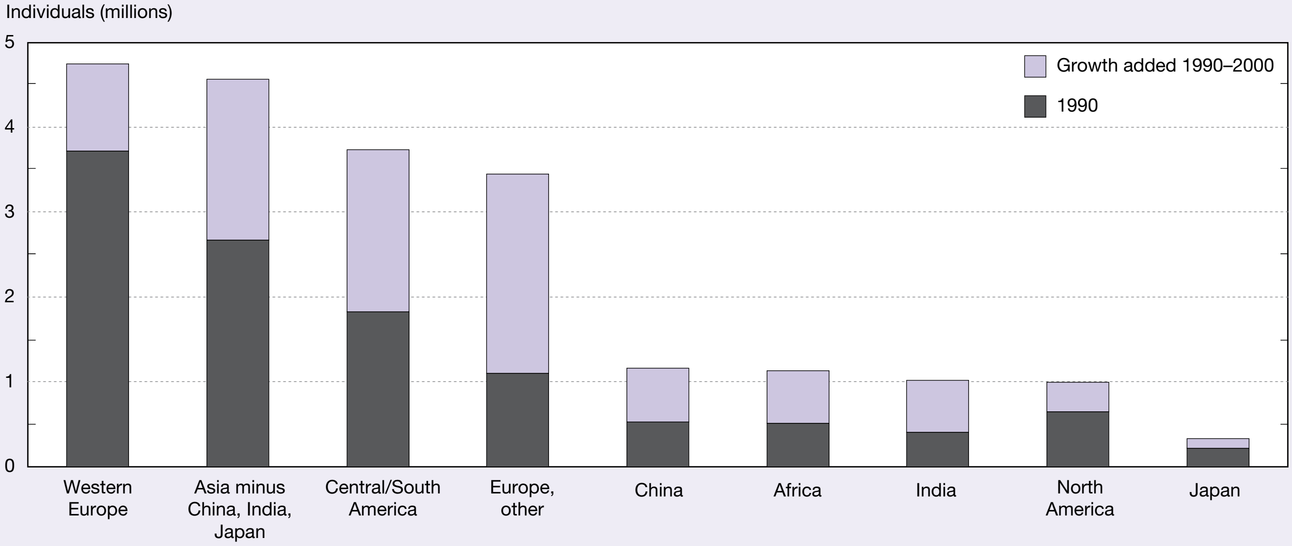
Figure O-26
Foreign higher education students in all fields, by country: 2002



SOURCE: Organisation for Economic Co-operation and Development, *Education at a Glance 2002* (2002).

Science and Engineering Indicators 2006

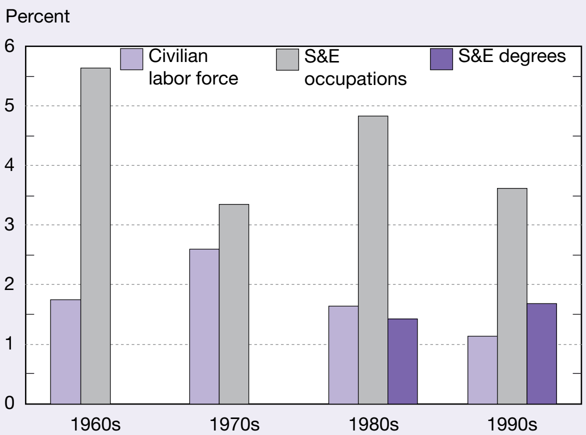
Figure O-27
Individuals with higher education living abroad, by country/region of origin: 1990 and 2000



SOURCE: F. Docquier and A. Marfouk, *Measuring the International Mobility of Skilled Workers (1990–2000)* (2004).

Science and Engineering Indicators 2006

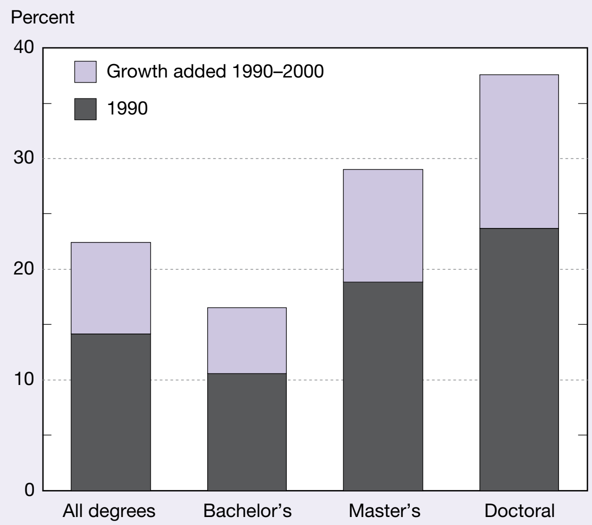
Figure O-28
Average annual growth of U.S. labor force, S&E occupations, and S&E degrees: 1960–2000



SOURCES: B.L. Lowell, Estimates of the Growth of the Science and Technology Workforce, Commission on Professionals in Science and Technology (forthcoming); *Economic Report of the President* (2002); and U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey (various years).

Science and Engineering Indicators 2006

Figure O-29
Share of foreign-born scientists and engineers in U.S. S&E occupations, by degree level: 1990 and 2000



NOTE: Data exclude postsecondary teachers because of Census occupation coding.

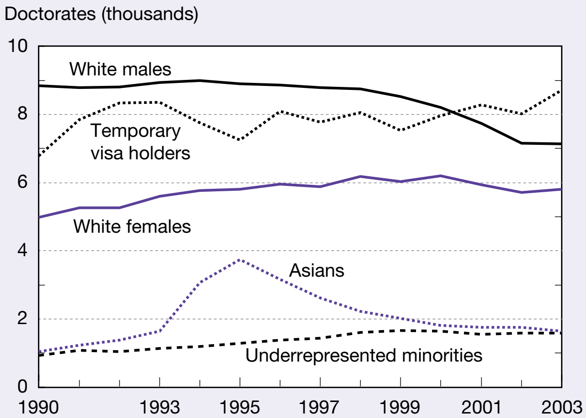
SOURCE: U.S. Census Bureau, 5-Percent Public-Use Microdata Sample, www.census.gov/main/www/pums.html.

Science and Engineering Indicators 2006

Foreign students earned one-third of U.S. S&E doctorates and 55% of engineering doctorates, whereas doctorates earned by U.S. white males dropped sharply.

The production of U.S. S&E doctorates since 1990 has been robust, rising from 23,800 to a record 28,800 in 1998 before dropping to 26,900 in 2003. The overall number depended heavily on foreign students. Students holding temporary visas earned between 6,800 and 8,700 doctorates a year (figure O-30)—in 2003 they earned one-third of the total number of doctorates, more than half of those in engineering, 44% of those in mathematics and computer science, and 35% of those in the physical sciences. The number of U.S. Asian students is inflated by the conversion of large numbers of

Figure O-30
S&E doctorates conferred by citizenship status and race/ethnicity: 1990–2003



NOTES: Physical sciences include earth, ocean, and atmospheric sciences. Social sciences include psychology. Whites, underrepresented minorities, and Asians include U.S. citizens and permanent visa holders only. Excludes unknown citizenship or race/ethnicity.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates; and WebCASPAR database, http://webcaspar.nsf.gov. See appendix tables 2-30 and 2-31.

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Chinese students with temporary visas to permanent status under the 1992 Chinese Student Protection Act.

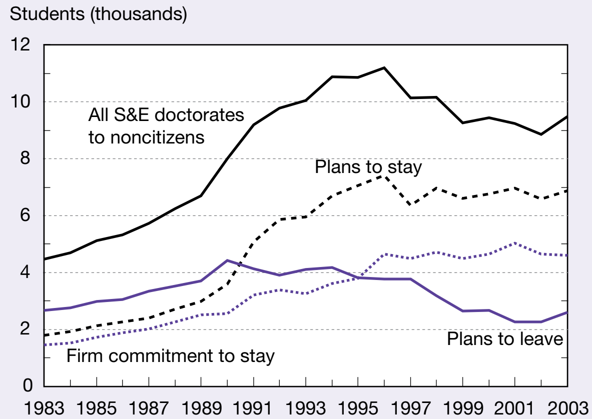
Large numbers of foreign doctorate holders continue to stay in the U.S. after receiving their degree.

Recent downturns in foreign enrollment notwithstanding, many foreign students pursue advanced study in S&E fields at U.S. universities. These students frequently choose to stay in the United States after earning their S&E degree. Beginning in the 1990s, a growing number of graduate students, doctorate holders, and postdoctoral fellows chose to remain in the country for further study or work. Since the mid-1990s, every year about 6,500–7,000 foreign students who earned a U.S. S&E doctorate planned to stay in the United States after receiving their degree (figure O-31). Through 2003, many of these students remained in the country for years after graduation: 53% of the 1993 doctorate recipients were working in the United States in 1997 and 61% of the 1998 cohort remained in the country in 2003. However, increasing international competition for foreign students raises questions about the continued viability of these high rates.

Asian locations that have been the source of two-thirds of foreign doctoral candidates in the United States are developing their own S&T infrastructures.

During the past two decades, two-thirds of foreign students earning a U.S. S&E doctorate were from Asia: about 20% from China and 10%–11% each from Taiwan, India, and South Korea (figure O-32). However, Asia is investing heavily in the development of knowledge-based economies

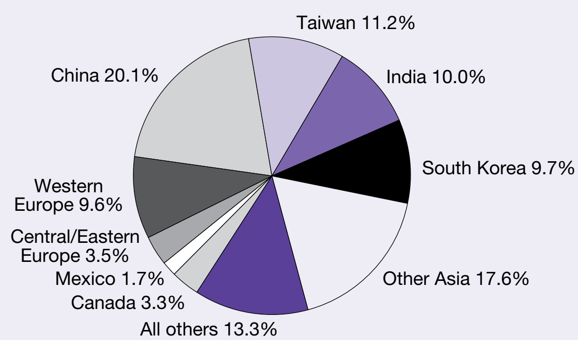
Figure O-31
Foreign student plans to stay in United States after receipt of U.S. S&E doctorate: 1983–2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations (2005). See appendix table 2-33.

Science and Engineering Indicators 2006

Figure O-32
Origin of foreigners earning U.S. S&E doctorates: 1983–2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates, special tabulations (2005).

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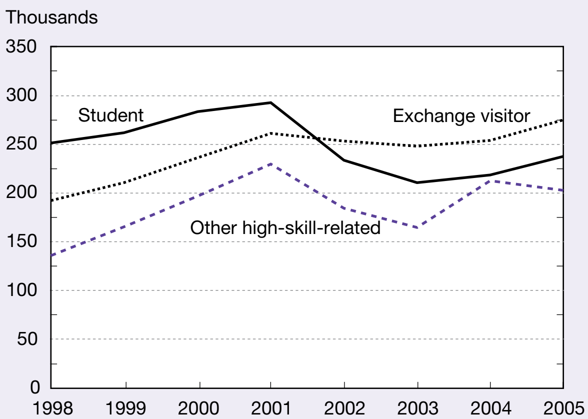
and higher education systems, and countries such as Japan are starting to import large numbers of Asian scientists and engineers. Thus, there is no assurance of a continued influx of students from this region to the United States, especially since other countries are creating immigrant-friendly policies for those with advanced S&E degrees.

Foreign student visas are recovering but remain down by one-fifth since 2001, and other high-skill visa categories are trending upward.

The U.S. reaction to the events of September 11, 2001, affected the flow of foreign-born scientists and engineers into the United States. The number of student, exchange visitor, and other high-skill-related visas issued annually grew rapidly during the 1990s but decreased sharply after September 11.

The number of applications declined because of increased difficulty in processing, higher cost, and heightened scrutiny of applicants. The number of visas issued reached a low point in 2003 and has since recovered. By 2005, the number of student visas issued had risen to their 2002 level, as the length of time for processing along with the difficulty in processing had decreased. The number of student visas issued remained below the 2001 level, while that for exchange visitors exceeded it. (figure O-33).

Figure O-33
Student, exchange visitor, and other high-skill-related temporary visas issued: 1998–2005



SOURCE: U.S. Department of State, Immigrant Visa Control and Reporting Division (1998–2005).

Science and Engineering Indicators 2006

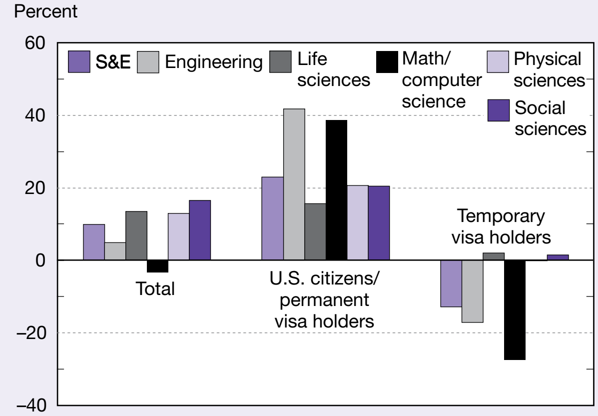
A leading indicator suggests declining foreign enrollments in advanced S&E study.

First-time, full-time enrollment in graduate study, a leading indicator, shows significant changes since 2001. The number of foreign students enrolling for the first time dropped sharply in 2003 compared with the 2001 level (figure O-34). The 2-year decline was most pronounced in mathematics and computer science (–28%) and engineering (–17%), fields heavily favored by foreign students. Gains by U.S. citizens and permanent visa holders more than offset these losses, with both engineering and mathematics and computer science rising by about 40%. However, these trends may be about to change again; data compiled by the Institute of International Education show an increase of about 2.4% in foreign graduate enrollment from 2003 to 2004.

Many retirements from the U.S. S&E labor force are impending.

Barring major changes in current trends, many individuals in the S&E labor force will retire in the coming decades. In 2003, 13% of S&E bachelor's degree holders, 20% of master's degree holders, and 28% of doctorate holders were 55 years old or older (figure O-35). Historically, by age 61 about half of the bachelor's degree holders no longer work full time; the same is true at age 62 for those with master's degrees and at age 64 for doctorate holders.

Figure O-34
Change in first-time full-time graduate enrollment in S&E, by citizenship status: 2001–03



SOURCES: National Science Foundation, Division of Science Resources Statistics, Survey of Graduate Students and Postdoctorates in Science and Engineering; and WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 2-16.

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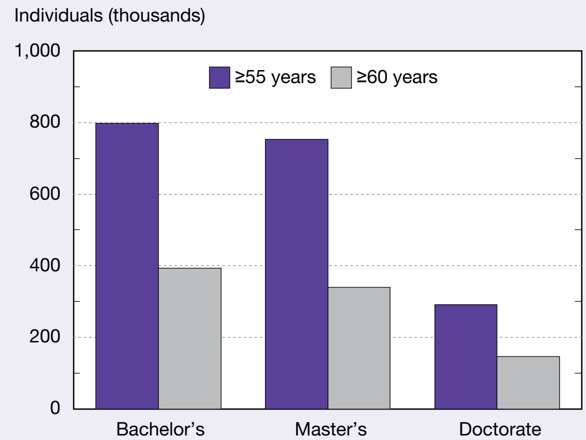
Figure O-35
Individuals in U.S. S&E labor force nearing retirement age, by degree level: 2003



NOTE: Preliminary estimates made in 2005 based on 2003 data

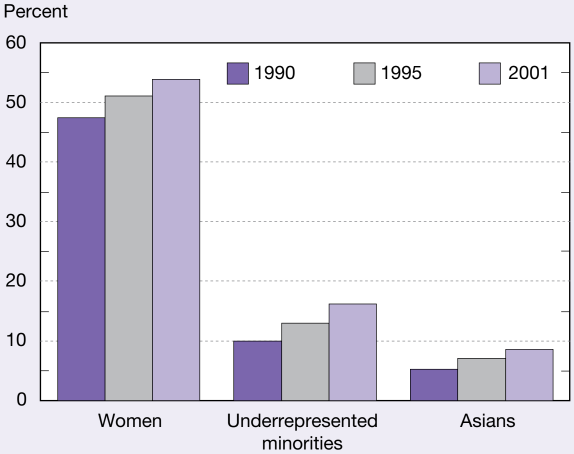
SOURCE: National Science Foundation, Division of Science Resources Statistics, National Survey of College Graduates, preliminary estimates (2005).

Science and Engineering Indicators 2006

Women and minorities earned increased shares of S&E degrees, including advanced degrees.

Among U.S. citizens and those who hold permanent visas, women and members of minority groups increased their share of S&E degrees at the bachelor's and higher degree levels. Beginning in 2000, women received half of these degrees, Asians received 10%, and other minorities received 18% (figure O-36). The number of S&E undergraduate degrees was 416,000 in 2002, the last year for which data are available. Three major trends since 1990 are a strong increase in the

Figure O-36
U.S. S&E bachelor's degrees earned by women and minorities: 1990, 1995, and 2001

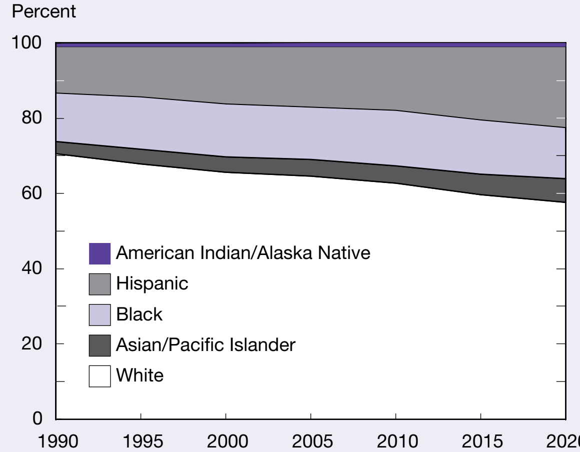


NOTE: U.S. citizens and permanent visa holders only.

SOURCES: U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey; and National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates; and WebCASPAR database, http://webcaspar.nsf.gov. See appendix tables 2-26 and 2-27.

Science and Engineering Indicators 2006

Figure O-37
Composition of U.S. college-age cohort: 1990–2020



SOURCES: U.S. Census Bureau, Population Division, 1990 Census, http://www.census.gov/population/estimates/nation; and Population Projections Program, Projections of the Resident Population by Age, Sex, Race, and Hispanic Origin: 1999 to 2100 (2000), http://www.census.gov/population/projections/nation/detail/d2001_10.pdf. See appendix table 2-4.

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social sciences and psychology, a sustained rise in life sciences followed by a gradual decline, and steep growth in computer science degrees beginning in the late 1990s.

Continuing demographic changes in college-age cohorts pose challenges to raising domestic S&E degree output.

Projected changes in the composition of successive U.S. college-age cohorts will present challenges to increasing the number of S&E degrees earned by U.S. citizens. The share of whites is projected to decline from 71% in 1990 to 58% by 2020; historically whites have been more likely than other groups (except Asians) to earn S&E degrees. The share of Asians is projected to increase to 6%. The Hispanic share will nearly double (from 12% to 22%), while the shares of blacks and other minorities will remain flat, at a combined total of about 15% (figure O-37).

The performance of U.S. students in elementary and secondary schools may raise concerns.

International and domestic assessments of the performance of American students present a mixed picture. Both U.S. fourth and eighth grade students scored above the international average on the 2003 Trends in International Math and Science Study (TIMSS), which measures mastery of curriculum-based knowledge and skills. TIMSS calculated the average of all participating countries, both developed and developing. However, U.S. 15-year-olds scored below the international average on the 2003 Programme for International Student Assessment (PISA), which measures students' ability to apply scientific and mathematical concepts and skills (figure O-38). OECD administers PISA, and PISA's average was based on scores from industrialized OECD countries only. In the United States, only about one-third of 4th and 8th grade students and less than 20% of 12th graders reached proficiency in mathematics and science tests administered by the National Assessment of Educational Progress; scores for underrepresented minorities were significantly lower. Proficiency in these tests denotes solid performance for the students' grade based on judgments of what students should know and be able to do in the subject assessed.

In sum, prospects for the U.S. S&E workforce are for slower growth, rising retirements, and increasing average age.

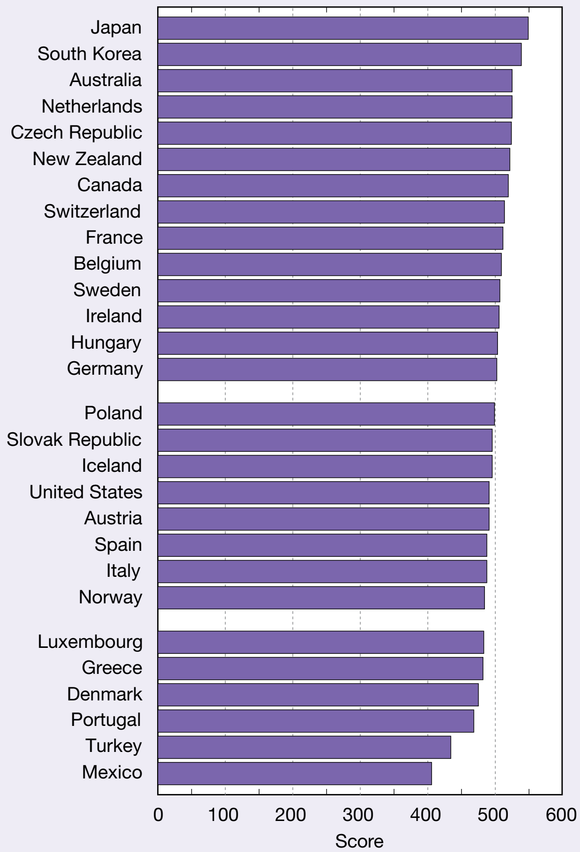
Taken together, and barring significant changes, current trends in degree production, retirement, and immigration suggest that the number of trained scientists and engineers in the labor force will continue to increase, but at a slower rate; the average age of S&E workers will rise; and the number of retirements will increase sharply over the next two decades. Declining degree production or immigration would accentuate these trends.

U.S. Academic R&D

Since 1990, inflation-adjusted academic R&D expenditures have almost doubled, driven by federal and institutional funds.

Expenditures for academic R&D reached $40 billion in 2003, the second-fastest growth of any U.S. R&D sector. The federal government supplied 62% of these funds,

Figure O-38
Average science literacy score of 15-year-old students, by country: 2003



SOURCE: Organisation for Economic Co-operation and Development, Programme for International Student Assessment (2003). See appendix table 1-14.

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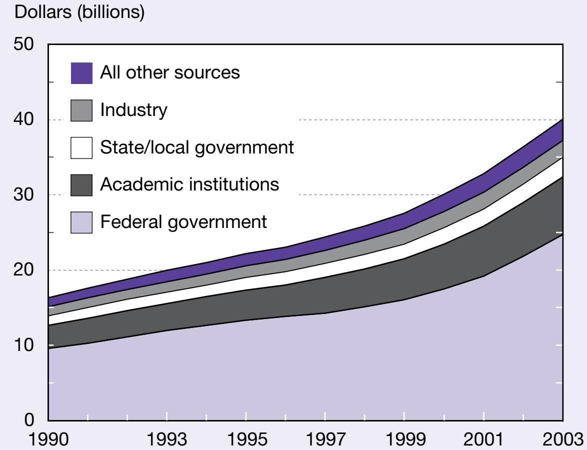
Figure O-39
Expenditures for academic R&D by source of funds: 1990–2003



NOTE: Current dollars; excludes capital expenditures.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Academic Research and Development Expenditures: Fiscal Year 2003 (forthcoming); and WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 5-2.

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up from 59% in 1990, reversing the long-declining share of federal dollars. The universities themselves provided an additional 19%. State government and industry support grew slowly, state government funding because of unfavorable budget conditions, industry funding because of retrenchment after the collapse of the dot.com industry (figure O-39). The life sciences share of academic research expenditures rose to 59%, whereas the shares of engineering and the physical sciences declined because their funding grew more slowly.

Academic laboratory construction is booming, but equipment spending is at a long-term low.

Extensive laboratory construction activities are currently under way; in 2002–03, almost half of all universities began construction projects. Investment for new laboratory space stood at $7.6 billion in 2003, with another $9.1 billion in projects scheduled to start in 2004 or 2005. Most of these expenditures were for the biological and life sciences (58%–60%) and engineering (14%). During most of the period, state and local governments supplied about one-third of the funds (and more in the mid-1990s); the federal government's share was 5% in 2002–03, reflecting the growing prominence of institutional sources, private donations, and forms of debt funding. Cutting-edge research also requires state-of-the-art research equipment. However, equipment spending, generally from operating funds, grew more slowly than overall research funds and reached a long-term low of 4.5% of academic R&D expenditures in 2003 (figure O-40).

Doctoral Scientists and Engineers in Academia

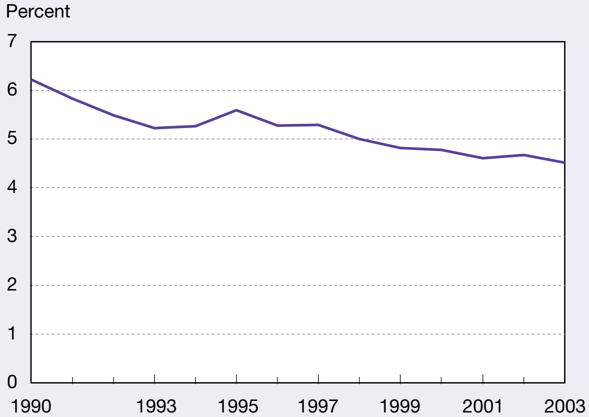
Fewer S&E doctorate holders are employed in academia, and fewer have traditional faculty positions, especially among young doctorate holders.

The academic doctoral labor force grew from 211,000 in 1991 to 258,000 in 2003, representing fewer than half of all employed S&E doctorate holders. In academia, the share of those with full-time faculty appointments declined from 82% to 75%. The share of full-time senior faculty fell below 55% in 2003, and the share of junior faculty was about 20%. These trends were accentuated for those with recent doctorates (figure O-41).

The academic doctoral labor force has become more diverse with the employment of more women, minority group members, and those born in other countries.

Increased conferral of S&E degrees to women and minority group members has been accompanied by rising academic employment among these groups. In 2003, women constituted 30% of all academic positions and 28% of full-time faculty. At a level of 8% in 2003, blacks, Hispanics, and American Indian/Alaska Natives remained a small proportion of total

Figure O-40
Expenditures for academic research equipment as share of total academic R&D expenditures: 1990–2003



NOTE: Excludes capital expenditures.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Academic Research and Development Expenditures: Fiscal Year 2003 (forthcoming); and WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 5-15.

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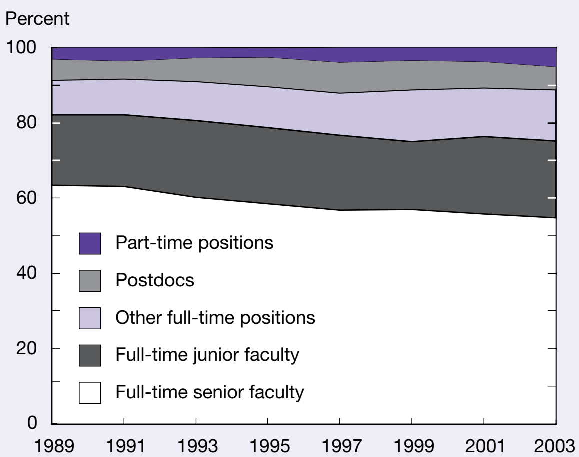
Figure O-41
Faculty and tenure-track status of academic S&E doctorate holders 4–7 years after receipt of doctorate: 1989–2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations. See appendix table 5-25.

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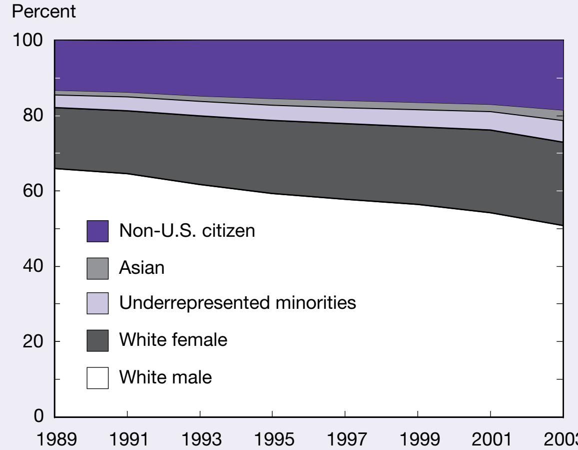
academic employment. The growing number of foreign-born doctorate holders in the academic labor force cannot be accurately determined from available data. Of those with U.S. degrees who are employed in academia, increasing proportions have been foreign born, rising from 17% in 1989 to 23% in 2003 (figure O-42).

Figure O-42
Composition of academic doctoral S&E workforce by race/ethnicity, sex, and citizenship at degree conferral: 1989–2003



NOTES: Non-U.S. citizens include both permanent and temporary visa holders. Other categories include only U.S. citizens.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations. See appendix table 5-25.

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The number of academic researchers is growing, but government support, despite strong growth, reaches fewer of them, especially those at the start of their careers.

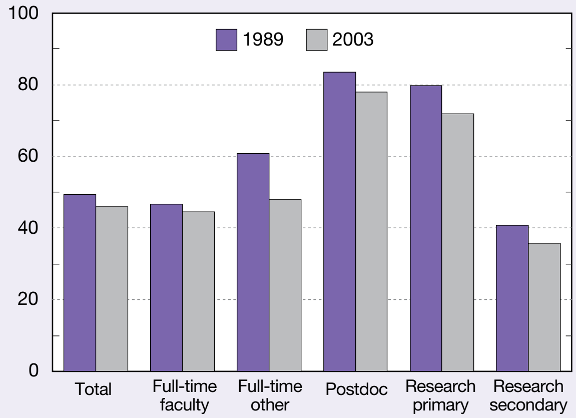
The numbers of individuals with primary work responsibility for R&D increased more rapidly than those with primary teaching responsibility. Academic researchers rely on the federal government for a significant share of their support. In 2003, 46% of all academic doctoral scientists and engineers and 72% of those for whom research was their primary work activity received federal support. These figures are less than those for the late 1980s and early 1990s for all fields except engineering, and the differences over time are especially pronounced for those with recent doctorates who are trying to establish a career (figure O-43).

Broader U.S. R&D Trends

Total U.S. R&D performance rebounded robustly after declining in 2002.

Total U.S. R&D expenditures more than doubled since 1990 and are projected to reach $313 billion in 2004. This strong rebound follows the first-ever reduction in 2002 that was caused by industry's retrenchment after the collapse of the dot.com industry. Adjusting for inflation, the 1990–2004 increase was 55%, with strong post-2002 gains in both federal and industry support. However, industry's share of total R&D support dropped from 70% in 2000 to 64% in 2004 as federal R&D investment rose, especially in security-related areas (figure O-44).

Figure O-43
Academic S&E doctorate holders receiving federal support for research: 1989 and 2003



SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Doctorate Recipients, special tabulations. See appendix table 5-37.

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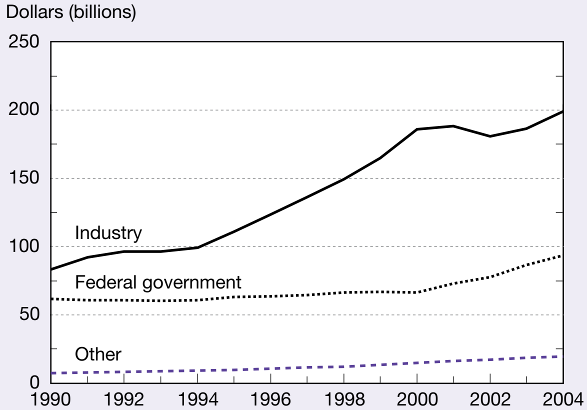
Figure O-44
R&D expenditures by source of funds: 1990–2004



NOTE: Current dollars; 2004 data are preliminary. Other includes $8 billion from universities' own funds.

SOURCE: National Science Foundation, Division of Science Resources Statistics, National Patterns of R&D Resources (annual series). See appendix table 4-3.

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R&D performance in concert with external partners is increasing.

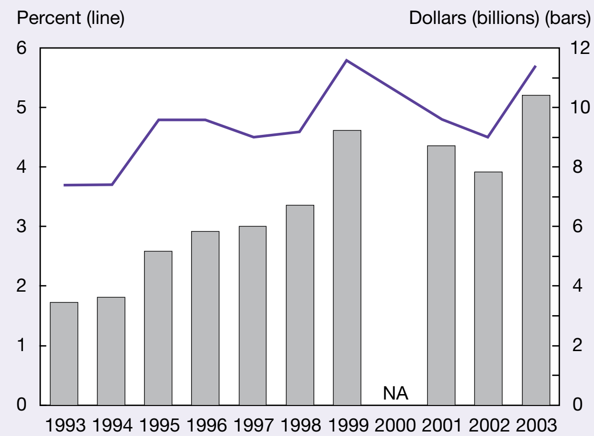
Firms are increasingly collaborating with external partners to conduct R&D in response to the growing complexity of R&D activities and the desire to reduce risks, share costs, expedite projects, complement internal capabilities, and enter new markets. This collaboration takes many forms, e.g., contracting out R&D and forming formal strategic alliances. In 2003, U.S. firms contracted $10.4 billion worth of R&D to other performers, up from less than $2 billion a decade earlier. This amounted to nearly 6% of internally performed R&D, up from less than 4% in 1993 (figure O-45). From 1993 to 2003, contracted R&D grew twice as fast as in-house R&D, and for manufacturing companies it grew nearly three times as fast.

Every year, many U.S. companies enter into formal strategic technology alliances domestically or with companies in other countries. With some year-to-year variation, about half of these alliances tend to be among U.S. partners only, with the other half primarily focusing on Europe. Formation of alliances increased rapidly during the early 1990s, peaked in 1995, and recently started increasing again. In 2003, U.S. companies announced nearly 500 new strategic alliances; 220 of them were among U.S. firms (figure O-46).

Federal stimulation of small business innovation is increasing.

A fixed portion of federal agencies' extramural R&D funds is set aside for competitive awards to small businesses to commercialize the results of federally funded projects. Small (Phase I) awards of short duration are designed to assess the scientific and technical feasibility of ideas with commercial potential; Phase II awards are intended for further development. Subsequently, the innovation must be brought to market with private-sector investment but without further federal support. Total funds awarded under this program have increased from about $500 million in the early 1990s to just under $1.7 billion in 2003 (figure O-47). The number of awards has nearly doubled, to just under 6,000.

Figure O-45
Contracted-out U.S. industrial R&D: 1993–2003



NA = not available

NOTE: Percent is ratio of contracted-out R&D to R&D performed internally.

SOURCE: National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development (annual series), http://www.nsf.gov/sbe/srs/indus/start.htm. See appendix table 4-34.

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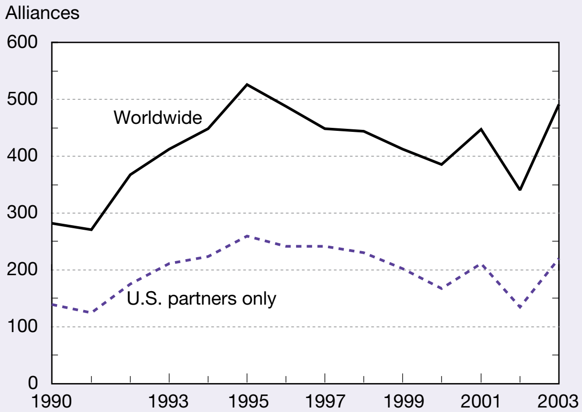
Figure O-46
New strategic technology alliances involving U.S. firms: 1990–2003



SOURCE: Maastricht Economic Research Institute on Innovation and Technology, Cooperative Agreements and Technology Indicators (CATI-MERIT) database, special tabulations. See appendix table 4-37.

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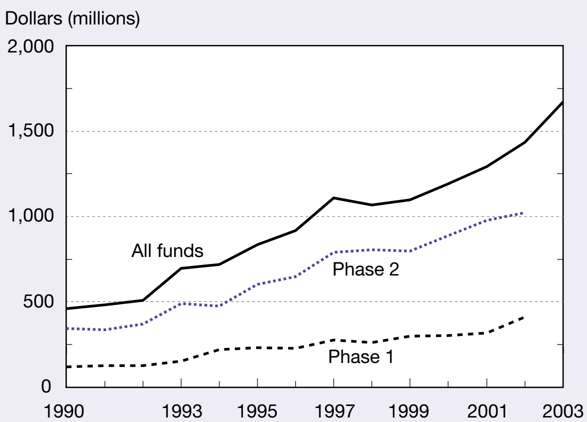
Figure O-47
Federal Small Business Innovation Research funds, by phase: 1990–2003



NOTE: Phase 1 awards are for feasibility assessment; phase 2 awards are for further development.

SOURCE: U.S. Small Business Administration, *Small Business Innovation Research Program Annual Report* (annual series). See appendix table 4-39.

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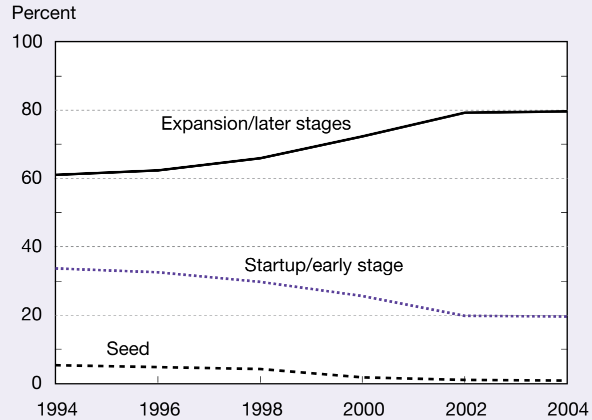
Figure O-48
Venture capital disbursements, by stage of financing: 1994–2004



SOURCE: Thomson/Venture Economics, special tabulations (May 2005). See appendix table 6-19.

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U.S. venture capital, the seedbed of startup companies, grows risk-averse.

At $21 billion, U.S. venture capital disbursements have again reached the level of the late 1990s after the collapse of the dot.com industry, but startup capital is scarcer than ever. The focus has shifted to expansion and later-stages funding, which consumed 80% of the funds disbursed in 2004. Startup and other early-stage funding dropped from 34% of funds in the early 1990s to 20%. Seed funding, the earliest stage with the most risk, received only $158 million, its lowest level since the early 1990s; this figure represented 0.8% of disbursed funds in 2004 compared with 5% through the mid-1990s (figure O-48). With the end of the surge in the dot.com industry, funds have shifted from Internet-specific firms to software and medical and health companies.

Conclusion

The globalization of R&D, S&T, and S&E labor markets continues. Countries seek competitive advantage by building indigenous S&T infrastructure, attracting foreign investments, and importing foreign talent. The location of S&E employment is becoming more internationally diverse and those who are employed in S&E have become more internationally mobile.

These trends affect every area of S&T. They reinforce each other, as R&D spending and business investment cross national borders in search of available talent, as talented people cross borders in search of interesting and lucrative work, and as employers recruit and relocate employees internationally.

Human capital is a key ingredient in these developments. Three factors affect the size of the U.S. S&E labor force that is available to compete for and create high-quality jobs in the worldwide knowledge economy: (1) retirements, because the number of individuals with S&E degrees who are reaching traditional retirement ages is expected to triple; (2) S&E degree production, because current trends will sustain growth but at a lower rate than before; and (3) potentially diminished U.S. success in the increasing international competition for foreign scientists and engineers, because many countries are actively reducing barriers to high-skilled immigrants while entry into the United States has become somewhat more difficult.

A prolonged slowdown in the growth of the U.S. S&E workforce would produce wage growth adjustments whose net effects in a mobile and integrated S&T marketplace are currently hard to assess. Better data, metrics, and models are needed to capture the evolving dynamics of international S&E labor markets and other aspects of S&T systems.

Notes

1. European Union (EU-15) includes Belgium, Denmark, Germany, Greece, Spain, France, Ireland, Italy, Luxembourg, the Netherlands, Austria, Portugal, Finland, Sweden, and the United Kingdom.

2. Asia-8 includes India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand.

3. Organisation for Economic Co-operation and Development (OECD) includes Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States.

4. Eight OECD nonmembers are Argentina, China, Israel, Romania, the Russian Federation, Singapore, Slovenia, and Taiwan.

5. EU-25 includes the EU-15 plus recent new members Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, and Slovenia.

6. The database is the combined ISI Thompson's *Science Citation Index and Social Sciences Citation Index.* The top journals are those within the top 1%, 5%, and 10% of journals with the highest ratios of citations to articles. Top articles are similarly defined as those with the top 1%, 5%, and 10% of citations in a given field.

7. Or closest year for which data are available.